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## Vertical and Lateral Movement of a Partial Flange Bearing Frog under HAL Traffic at FAST

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### Summary

Transportation Technology Center, Inc. (TTCI) is continuing to monitor the performance of a prototype of a partial flange bearing frog in a No. 11 turnout at the Facility for Accelerated Service Testing (FAST).

The railbound manganese frogs tested previously at this location had relatively short service life (i.e., 150 MGT), where mainline side frog heel failures were common. Although the partial flange bearing frog in test has required frequent maintenance to correct lateral misalignment, it has not experienced casting or rail failures during more than 240 million gross tons (MGT) of heavy axle load (HAL) traffic on the main line and more than 3 MGT on the diverging route.

TTCI conducted a test in July 2010 to measure vertical and lateral displacement in the frog area under HAL traffic. The results of measurements taken to quantify the vertical and lateral movement of the frog under HAL traffic are as follows:

- The frog is located in 300-foot tangent track between reverse curves of 5 and 6 degrees
  - This location has relatively high net axle lateral forces as measured at a load station in the same tangent track as the frog:
    - 7 percent of wheelsets exceed 10,000 pounds
    - 2 percent of wheelsets exceed 12,000 pounds
  - Based on the above, the frog guards move the wheelsets:
    - Away from the high rail of the previous curve in facing point moves
    - Toward the high rail of the previous curve in trailing point moves
- All moves through the frog resulted in lateral displacements
  - The mainline facing point moves resulted in the largest permanent lateral displacements. This was attributed to the flangeway guard engaging the high lateral force wheelsets to move them away from the high rail of the previous curve.
  - The mainline trailing point moves resulted in less permanent lateral movement. An occasional wheelset would strike the relatively short heel end guard. This resulted in large elastic lateral displacements but less permanent displacement.
  - Diverging route trailing point moves also resulted in lateral displacements.

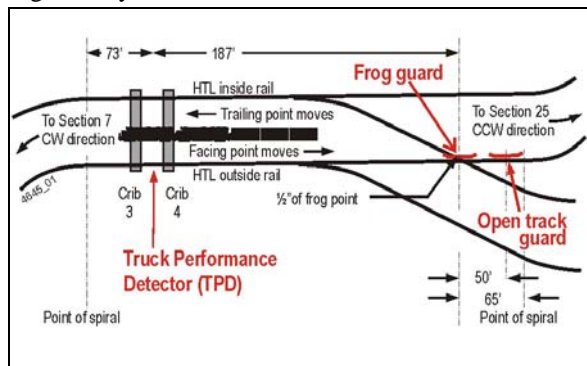
Research will continue to determine if a track modification can be introduced to reduce the lateral movement in the frog area.



**INTRODUCTION**

TTCI is testing a prototype of a partial flange bearing frog built by Progress Rail Services at FAST in the High Tonnage Loop (HTL). The product named Lift Frog is located in short tangent track between two reverse curves, as Figure 1 shows.

Partial flange bearing frogs function by providing ramps for diverging route wheels to climb over the mainline rail and descend back to nominal track level. This frog has a combination of tread bearing and flange bearing ramps. It uses a tread bearing ramp to raise the diverging running surface so that the wheel flange tip will be at the same elevation as the top of the mainline rail at the toe end of the frog. It uses a flange bearing ramp on the heel end of the frog, from the point of frog and beyond.<sup>1</sup>



**Figure 1. Layout of the Track Geometry Surrounding the Flange Bearing Frog**

The lateral misalignment in the frog area, shown in Figure 2, occurred as a result of regular HAL traffic at turnout No. 405. The frog has required maintenance for realignment at about 25 MGT intervals during a period of performance of 240 MGT of accumulated tonnage over the main line and about 3 MGT through the turnout. Visual inspection pointed to lateral wheel impacts at the flair of the frog’s guard during mainline trailing-point operations as possibly the primary cause of the misalignment problem.

The track displacement measurements were taken in July 2010 to evaluate the cause of lateral misalignment in the frog.

On September 17, 2010, the transition between the flair of the guard and the main part of the guard was ground in an effort to reduce the severity of the wheel impacts. On October 12, 2010, a 26-foot guardrail was installed in open-track about 50 feet ahead of the frog heel to help guide the wheels away from the frog guard. Neither of these potential remedies eliminated the misalignment problem.



**Figure 2. Lateral Misalignment in the Area of the Partial Flange Bearing Frog from HAL Train Operations on the HTL**

**Test Train**

A short dedicated HAL test train, consisting of two 6-axle locomotives and three loaded (315,000 gross rail load) coal cars, was used for this test. The vertical and lateral displacement of the track was measured as the train passed over the frog on the main line and through the diverging route.

The test train was set up with the locomotives leading for the trailing point runs on the main line (clockwise direction around the HTL) and for the trailing point runs through the turnout. Conversely, the loaded cars were leading for the facing point runs on the main line (counterclockwise around the HTL) and for the facing point moves through the turnout. The speed of the test train over the main line in both directions was 20 mph for the majority of the runs, except for one at 29 mph and one at 40 mph. The train ran through the turnout at 10 mph in both directions. A total of 35 runs were made over the frog; 31 on the main line and 4 through the turnout.

**Measurement Equipment and Setup**

A rail-base-mounted fixture was fabricated and fastened to the mainline running rail at the location of peak lateral misalignment. The peak of the misalignment was directly in line with the location where the back of the wheels impact the flair of the frog guard — about 25 inches from the 1/2-inch point of the frog. New wood switch ties had been installed through the frog area prior to the test.

The ground-reference measurements of vertical and lateral displacement at the frog were made using Linear Variable Differential Transformers (LVDT) mounted on 5-foot-long steel rods driven through the ballast section into the subgrade. The rail-base fixture held the two steel plates used as contact targets for the two LVDTs. Figure 3 shows the horizontal LVDT on the gage side of the mainline running rail used to measure the lateral displacement. The LVDT on the field side measured the vertical displacement. The data sample rate was 512 Hz.



**Figure 3. LVDTs used for Ground-Reference Measurements of Vertical and Lateral Displacement in the Frog Area under Traffic**

**Measurements**

The LVDTs measured the vertical and lateral displacements in the frog area as the test train traveled in trailing point and facing point directions on the main line and as it diverged off the HTL (facing point) and back onto the HTL (trailing point). See Figure 1. Figure 4 shows the contact band (lower area of orange painted section), where the back of the wheels made contact along the main frog guard when the train was

operating in the facing point direction. In the trailing point direction, the wheels impact the flair at the end of the contact band and just above it. In both cases, the train was running on the main line. As indicated in the photograph, wheel impact on the flair of the frog in the trailing point direction occurred even at 40 mph coming out of the curve. The frog and its guard are on the extended high rail. This photo was taken during the vertical/lateral measurement test, before the flair was ground and the 26-foot open-track guardrail was installed.



Figure 4. Back of Wheel Impact Location on the Flair of the Frog Guard while running on the Main Line at 40 mph in Trailing Point Direction

Results

Figure 5 shows the cumulative lateral displacement (permanent misalignment) and the vertical displacement resulting from all the runs, including four runs on the diverging route, as a function of runs over the frog. Figure 5 shows that the track moved toward the main line as expected. Total movement was just under 0.85 inch. The slope of the curve suggests that the diverging runs (runs 20 through 23) and the main line runs contributed similarly to the permanent misalignment of the frog area. The upward shift in the vertical displacement during the turnout moves is likely the result of upward teetering as the train ran with wheels over the frog and the turnout rail. When the mainline passes resumed with run 24, where the train returned to running with wheels over the frog and the mainline rail, the vertical curve shifted back down indicating the mainline running rail resettled (the LVDTs were mounted on the mainline rail). By about run 25, it appears the track structure was approaching the maximum possible permanent misalignment as indicated by the shallowing slope.

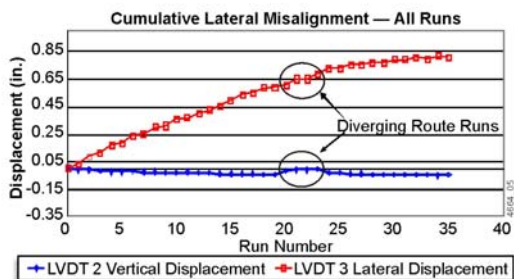


Figure 5. Cumulative Lateral Displacement (permanent misalignment) and Vertical Displacement resulting from All Runs over the Frog

To determine the direction of mainline traffic that had the most influence on the development of the permanent misalignment, the change in the permanent lateral position of the track was plotted for each run (change equals the difference

in lateral position before and after the run). The odd number runs were in the trailing point direction (direction of wheel impact), and the even number runs were in the facing point direction. Note that the two locomotives were leading in the trailing point direction and the three loaded cars were leading in the facing point direction. Figure 6 shows the change in vertical and lateral displacement for the trailing point mainline runs only. The spike at run 15 of the lateral displacement curve coincides with the 40 mph run. Run 13 was at 29 mph (all other runs were at 20 mph; the turnout runs were at 10 mph).

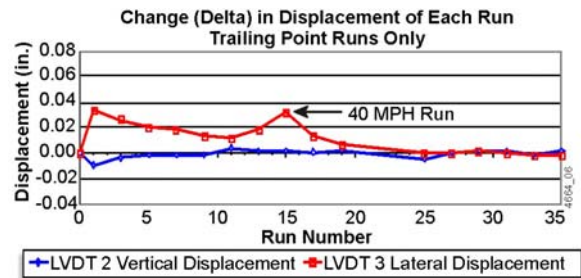


Figure 6. Change in Vertical and Lateral Displacement resulting from Each Trailing Point Run over the Frog on the Main Line

Figure 7 illustrates the same type of change in displacement data as the one in Figure 6 but for mainline runs over the frog in the facing point direction only. The diverging route data was excluded in both graphs.

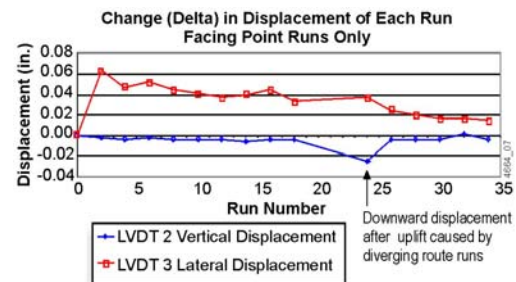


Figure 7. Change in Vertical and Lateral Displacement resulting from Each CCW Run over the Frog on the Main Line

A comparison of Figures 6 and 7 indicates that the mainline runs over the frog in the facing point direction contributed more to the permanent misalignment in the frog area than the runs in the trailing point direction. It appears the permanent displacement resulting from trailing point traffic reached steady state after about the 25<sup>th</sup> run.

During the first run of the test (and subsequent trailing point direction runs), two wheels impacted the guard flare; they were the leading axle of the leading truck of two different cars. Figure 8 shows the two impacts recorded in the first run. Both impacts are seen as small spikes in the positive direction toward the misalignment. Immediately after each small positive spike, there is a much larger spike in the negative direction toward the frog, which was likely caused by rebound after the initial high-frequency impact. The spring strength of the LVDT may not have been adequate to keep the LVDT's plunger in contact with the surface of the steel plate as the track rebounded. This would have caused the plunger to be

launched into the LVDT tube then returning to contact the plate. The large rebound spike in the data served to pin point the wheels that impacted the guard. The permanent misalignment measured as a result of the entire first run was about 0.31 inch.

Figure 9 shows the response of the track in the frog area during the second run (facing point direction) of the test. In this run, the hits are absent but the permanent misalignment measured was about 0.062 inch, twice that of run 1.

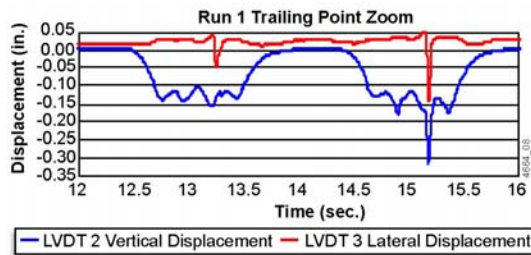


Figure 8. Zoomed-in View of the 2-Wheel Impacts Recorded during Run 1 in Trailing Point Direction

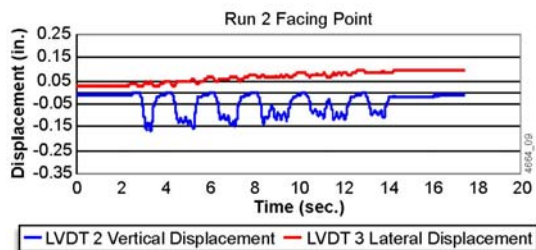


Figure 9. Vertical and Lateral Displacement during the Second Run of the Test, Facing Point — Permanent Lateral Misalignment resulting from this Run was 0.062 inch

### Truck Performance Detector Data

A truck performance detector (TPD) is located on short tangent track between the curve in Section 7 and the 405 turnout of the HTL. As the test train traveling in the facing point direction on the main line exits the curve, it passes over the TPD before entering the turnout toward the frog. In the trailing point direction, the test train passes over the frog and exits the turnout before it passes over the TPD. The TPD is about 187 feet from the ½-inch point of the frog, and the curve spiral is about 73 feet from the TPD — a total of 260 feet from the curve to the frog, as Figure 1 shows.

The net axle lateral (NAL) force in this case is defined as the lateral force on the inside rail (inside rail of the HTL) minus the lateral force on the outside rail (outside rail of the HTL). An analysis of the NAL force measured with the TPD indicates 7 percent of the 424 axles applied more than 10,000 pounds, 2 percent more than 12,000 pounds, and the maximum was about 16,000 pounds in the direction of misalignment. Assuming some of those axles are still applying high lateral forces to the high rail when they reach the frog (187 feet after they pass over the TPD), it is likely they may be the major cause of the permanent misalignment as the back of those

wheels make contact along the frog guard and effectively push the frog segment of the turnout panel out of alignment.

Rail profile measurements taken of the frog guard along the back of wheel contact band indicate very low wear suggesting that perhaps most of the axles may have come off the extended high rail by the time they reach the guardrail, and that the few high lateral wheels that do contact the guard are sufficient to misalign.

The NAL forces measured at the TPD for the trailing point runs indicate that 73 percent of the axles applied less than 4,000 pounds in the direction of misalignment — the maximum was about 12,000 pounds. It is important to note that the axles traverse the frog before they pass over the TPD in the trailing point direction.

### CONCLUSIONS

Misalignment of the turnout panel in the frog area continues to be a problem that requires frequent maintenance. A guardrail that was installed at the approach to the heel of the frog for trailing point traffic, when it was assumed that impacts in that direction were causing the misalignment, did not resolve the problem. LVDT data indicates that traffic in all directions over the frog contributes to the misalignment. Trains moving in the facing point direction on the main line, however, did more to misalign than trailing point trains or diverging route moves. Furthermore, the high NAL forces measured at the TPD between the curve and the turnout during facing point moves appear to contribute more to the misalignment than the high frequency wheel impacts documented during the trailing point moves.

The underlying problem may be the close proximity of the curved track, where the trucks/axles have not yet fully settled into tangent-track mode when they reach the frog.

### FUTURE WORK

Additional research is needed to determine if a track modification can be introduced, perhaps a guardrail on the approach to the turnout for facing point traffic to reduce the effect of the poorly steering trucks/axles. Another option may be to relocate the frog where it is further from curved track.

### Acknowledgments

The authors acknowledge Ira Kalb (TTCI instrumentation supervisor) and Devin Sammon (engineering student intern) for their technical contributions and R.B. Wiley (TTCI) for the research and analysis of the TPD data.

### References

1. Jimenez, Rafael, David Davis, and Joseph LoPresti. April 2010. "Initial Wear Performance Evaluation of Partial Flange Bearing Frogs for Turnouts in Heavy Axle Load Service." *Technology Digest* TD-11-012, AAR, TTCI, Pueblo, CO.
2. Davis, David D., at al. December 2009. "Initial Performance Evaluation of Partial Flange Bearing Frogs for Turnouts in Heavy Axle Load Service." *Technology Digest* TD-09-031, AAR, TTCI, Pueblo, CO.

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